The Identification of Failure Modes in the Elevator Installation Process of a Case Company in Thailand by FMEA

Tawan Suwankanit

National Formosa University

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This study analyzes the installation process of the elevator of a case company in Thailand by using an expert review method, which identifies failure modes and their associated effects and possible causes of the installation process. The qualified experts assign the severity, occurrence, and detection ranking to each failure mode to get the risk priority number. After that, the Pareto principle is used to discover the few critical failure modes for developing the remedy action plan. The result of this study determines the actions for the elevator installation process to perform corrective actions which can prevent the failure modes from happening, minimize the waste, and reduce the unreliability.

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Author: National Formosa University, Taiwan, Republic of China.

I. INTRODUCTION

During the last decade, elevator plays an important role to make daily life much easier. It has been used for a long time since the first electric elevator in 1880 in Germany [1] and has continuously developed a lot of technology. Besides, the smart elevator has been used in the elevator market in Asia-Pacific (APAC) for the period 2018 to 2022, which include Thailand as well [2]. This will help Thailand's elevator increase its market and develop a new technology that can identify and predict the problems.

Thailand occasionally has tragic news caused by an elevator from time to time. It may not happen very often, but when it happened, it is horrified and unexpected. Moreover, the causes of injuries and deaths are not just from the users, but it appeared to come from workers when install, repair, and maintenance of the elevator as well [3].

Therefore, the objective of this study aims to identify and analyze the risks in the installation process of an elevator at the case company in Thailand by using failure mode and effects analysis to minimize the chance of failures. The result of this research will help the case company and other Thailand's elevator companies to decrease the incidents that happen unanticipated and unintentionally, which the outcome is in damage or injury.

II. Study Design of PFMEA in This Research

The process failure mode and effect analysis in this study can be done in 10 steps as follows:

- Step 1: Review the process
Interviewed the relevant person (Department manager, Project manager/engineer, Site engineer, supervision, QC technician, etc.) in the installation division at the case company in Thailand to get the installation workflow, and method.

- Step 2: Identify the potential failure modes
Examine the possible failures thoroughly to discover the failure modes by using the question "what can go wrong?" [4].

- Step 3: Identify the potential effects of failure

Contemplate the potential failures, and think about what are the consequences of it.

- Step 4: Identify the possible causes of failure

Consider the potential failures, and think about what are the reason that makes this failure happen.

- Step 5: Assign the severity ranking

Depend on the severity of the effects of failure. This study decided the severity ranking from 1 to 10 as shown in Table 1.

Table 1: Criteria for Ranking Severity (S) in PFMEA

Effect	Severity Criteria	Ranking
Extremely serious	Failure mode may cause fatal injury to end user of the elevator.	10
	Failure mode may cause fatal injury to installation workers.	9
	Failure mode may cause injury (but not fatal) to end user of the elevator.	8
	Failure mode may cause injury (but not fatal) to installation workers.	7
Very serious	Failure mode may cause stall or interruption of the installation process and the customer asks great compensation and never place order again.	6
	Failure mode may cause stall or interruption of the installation process and the customer asks great compensation but will still place order in the future.	5
Serious	Failure mode may cause interruption of the installation process for a short period of time and the customer complaints about it.	4
	Failure mode may cause some malfunction that create a bad quality image for the end user of the elevator.	3
	Failure mode may cause minor defects and inconvenience of the end user of the elevator.	2
Less serious	Failure mode will not cause any noticeable problem or defect.	1

- Step 6: Assign the occurrence ranking

Hinge on the probability of it happening by using the question "how often will the failure modes occur?" [4]. This study determined the occurrence ranking by using the probability of failure(s) occurrence. Mean time between failures (MTBF) has been used in this ranking from 1 to 10 as shown in Table 2.

Table 2: Criteria for Ranking Occurrence (O) in PFMEA

Probability of Failure Occurrence	Possible Failure Rates Criteria	Ranking
Very high: Failure is almost certain.	Mean time between failures less than 1 hour.	10
	Mean time between failures less than 4 hours.	9
High: Frequent failures.	Mean time between failures less than 8 hours.	8
	Mean time between failures less than 1 day.	7
Moderate: Infrequent failures.	Mean time between failures less than 1 week.	6
	Mean time between failures less than 2 weeks.	5
	Mean time between failures less than 3 weeks.	4
Low: Few failures.	Mean time between failures less than 1 month.	3
	Mean time between failures less than 2 months.	2
Remote: Failure unlikely.	Failure is eliminated through the process.	1

- *Step 7: Assign the detection ranking*

Detection ranking can be decided by the chances the defect that would lead to failures can be found. This study defined the detection ranking with current controls, the ability for current controls to detect cause(s), from 1 to 10 as shown in Table 3.

Table 3: Criteria for Ranking Detection (D) in PFMEA

Detection	Likelihood of Detection by Process Controls	Ranking
Impossible	Failure mode is impossible to detect even the extra sophisticated equipment is used.	10
Extremely difficult	Failure mode is almost impossible to detect even the extra sophisticated equipment is used.	9
Very difficult	Failure mode can be detected when the extra sophisticated equipment is used thoroughly.	8
	Failure mode can be easily detected by using the extra sophisticated equipment.	7
Difficult	Failure mode can be detected by using the extra general equipment thoroughly.	6
	Failure mode can be easily detected when the extra general equipment is used.	5
Not difficult	Failure mode can be detected by technician or QC inspector when the inspection SOP is followed thoroughly.	4
	Failure mode can be easily detected by technician or QC inspector when the inspection SOP is followed.	3
Easy	Failure mode can be easily and visually detected by technician or QC inspector.	2
Very easy	Failure mode can be easily and visually detected by installation worker.	1

- *Step 8: Collect and analyze the data*

Collect the severity, occurrence, and detection rating scores from the questionnaires that sent it to 13 related persons in the installation of an elevator at the case company in Thailand and analyze the rating scores to get the median number of severity, occurrence, and detection rating scores.

-*Step 9: Calculate and ranking the risk priority number*

Multiply the average severity, occurrence, and detection rating scores and prioritize the highest risk priority number of process.

- *Step 10: Develop the action plan*

To identify the critical failures, the Pareto principle has been used to discover the highest 20 percent of risk priority number from the installation of an elevator process (see Figure 1) which the improvement will be elaborated and recommended.

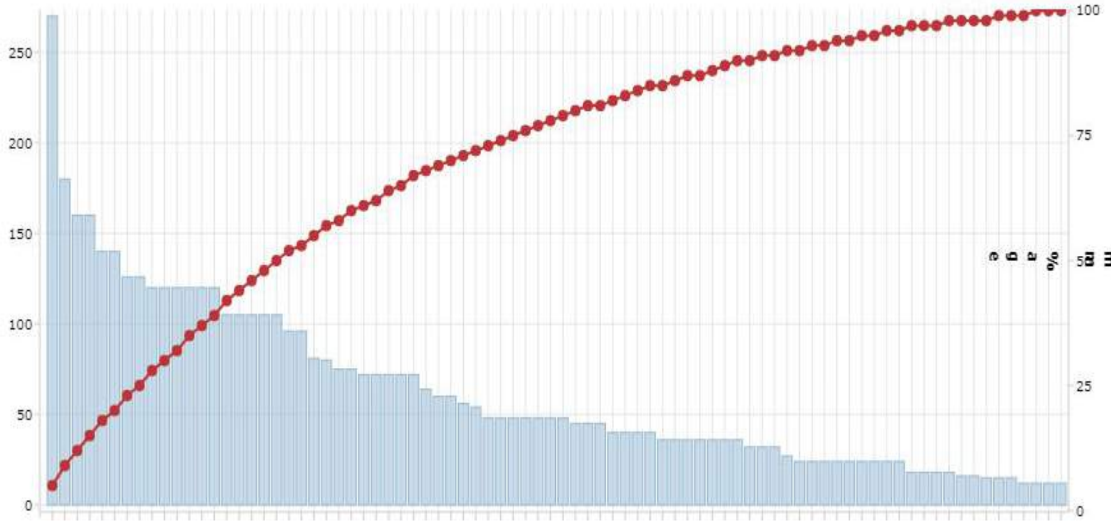

Figure 1: The Pareto Chart

The Pareto principle also known as the 80/20 rule, or the Pareto rule defines that 80 percent of the effects come from 20 percent of the causes [5]. Therefore, in this study will develop the action plan for 6 possible causes of failure which have the highest risk priority number that is 20 percent of the cumulative percentage of all causes. This is shown in Table 4.

Table 4: Summary of Failure Modes

Rank	Failure Mode(s)	Effect(s) of Failure	Potential Cause(s)	Recommendation	RPN
1	F-5.2. Have not installed by the original process that make it non-standard.	E-5.2.1. Cause of death by accident or injury.	C-5.2.1.1. The carelessness of workers.	All the workers should have been trained to follow the standard operating procedure and have the written and practical examination for their permit.	270
2	F-5.1. Do not wear safety and protection.	E-5.1.1. Cause of death by accident or injury.	C-5.1.1.1. The carelessness of workers.	Workers need to pay the compensation, or get the stop work order and never return to work in that project again, or both.	180
3	F-4.1. The hoistway structure is not in a straight line from pit to overhead.	E-4.1.1. Delay the installation progress.	C-4.1.1.1. Human errors from the main contractor.	Project manager/engineer needs to talk and provide the equipment to the main contractor, and send the subcontractor to work alongside them and tell them the errors that we can accept.	160
4	F-4.2. The hall structure opening is not in a straight line from pit to overhead.	E-4.2.1. Delay the installation progress.	C-4.2.1.1. Human errors from the main contractor.	Project manager/engineer needs to talk and provide the equipment to the main contractor, and send the subcontractor to work alongside them and tell them the errors that we can accept.	160
5	F-3.3. Incorrect door opening and block out of the structure.	E-3.3.1. Delay the installation progress (hall doors and hall accessories part).	C-3.3.1.1. The main contractor does not follow the approved shop drawings.	Project manager/engineer needs to tell them to follow the approved shop drawings, and send coordinator and supervision to watch and observe their work.	140
			C-3.3.1.2. Human errors from the main contractor.	Project manager/engineer needs to talk and provide the equipment to the main contractor, and send the subcontractor to work alongside them and tell them the errors that we can accept.	140

III. CONCLUSION

This study used PFMEA method to discover the failure modes, effects of failures, and possible causes of failures and determine the risk priority number (RPN) in the installation of a specific elevator at the case company in Thailand. It appeared that 34 failure modes have been identified along with 47 effects and 82 possible causes of failures. The recommendations have been given to those 6 possible causes of failures, according to the Pareto principle that uses 20 percent of their highest risk priority number.

It comes as no surprise that all of the highest 6 risk priority numbers have the causes of failure from the lack of responsibility of humans, and more than half of them are from the external factors which make the level of the detection of the criteria very high. Therefore, the problem might be in the transmission between the case company and the company that works with, and also the laziness of employees themselves.

To add to it, if the case company can be prevented, and intercepted or terminated the potential causes of these failure modes by using the recommendations in Table 4. The installation of a specific elevator process at the case company will be more efficient. This can help the case company to comprehend and examine the fundamental causes of failures in the installation of an elevator process, and can be applied to other processes of an elevator as well.

IV. LIMITATION AND FUTURE WORK

It's very rare to find the research about the installation of an elevator and apply the process failure mode and effects analysis method to improve it especially in Thailand, which means that there are a number of limitations related to this study. The most complex is to interviewed and discussed with the respondents from the case company in Thailand who take part in the questionnaire owing to the communication and misunderstanding between researcher and participants. Also, some information is classified and cannot be disclosed or revealed that make it difficult for the researcher to examine and conduct the research. In spite of that, it is fortunate for the researcher that had worked with them at the case company before so they are strongly eager to help in this study but it still took a long time to gather as much as sensible, logical, and rational information.

Another limitation is that, although the case company is one of the reliable elevator company that brings high quality innovations, reliable technologies, and efficient production processes but different companies have different processes and procedures. Also, the participants in this study are only from the installation division at the case company that has experience at least 5 years in the related position of the installation process.

By the research's limitations, this study focused on the installation of an elevator at the case company in Thailand. It can be extended into other processes like maintenance, repair, service, etc. or even the whole process of the elevator. Moreover, future research can use these limitations as a representative to conduct more comprehensive studies.

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